US009415421B2

(12) **United States Patent**
Kozawa et al.

(10) **Patent No.: US 9,415,421 B2**
(45) **Date of Patent: Aug. 16, 2016**

(54) **POWDER CLASSIFYING DEVICE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 182 days.

(21) Appl. No.: **13/885,589**

(22) PCT Filed: **Oct. 14, 2011**

(86) PCT No.: **PCT/JP2011/073635**

§ 371 (c)(1),
(2), (4) Date: **May 15, 2013**

(87) PCT Pub. No.: **WO2012/066885**

PCT Pub. Date: **May 24, 2012**

(65) **Prior Publication Data**

US 2014/0021109 A1 Jan. 23, 2014

(30) **Foreign Application Priority Data**

Nov. 16, 2010 (JP) 2010-256053

(51) **Int. Cl.**
B04B 5/10 (2006.01)
B07B 7/083 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC . ***B07B 7/083*** (2013.01); ***B07B 7/08*** (2013.01); ***B07B 11/04*** (2013.01); ***B07B 11/06*** (2013.01)

(58) **Field of Classification Search**
CPC B02C 23/10; B07B 4/02; B07B 7/10; B07B 7/08; B07B 7/083; B07B 11/04; B07B 11/06
USPC 209/138, 139.1, 139.2, 143, 154, 710, 209/717, 718, 722
See application file for complete search history.

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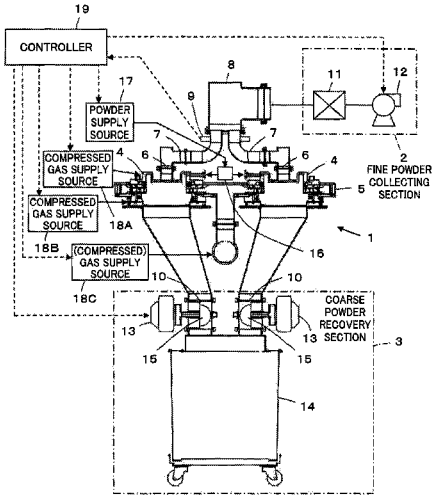
(57) **ABSTRACT**

A powder classifying device includes a plurality of powder classifiers that impart a whirling motion to powder with whirling gas streams to classify the powder into coarse powder and fine powder, a gas supply source that supplies the plurality of powder classifiers with gas for generating the whirling gas stream, a powder supplier that supplies the plurality of powder classifiers with powder having a particle size distribution, a fine powder collecting section that collects fine powder classified by each of the plurality of powder classifiers, a coarse powder recovery section that recovers coarse powder classified by each of the plurality of powder classifiers, and a controller that controls flow rates of gases supplied to the plurality of powder classifiers so that a classification point is substantially equal among the plurality of powder classifiers.

7 Claims, 4 Drawing Sheets



(51) **Int. Cl.**

B07B 7/08	(2006.01)
B07B 11/04	(2006.01)
B07B 11/06	(2006.01)

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FIG.1

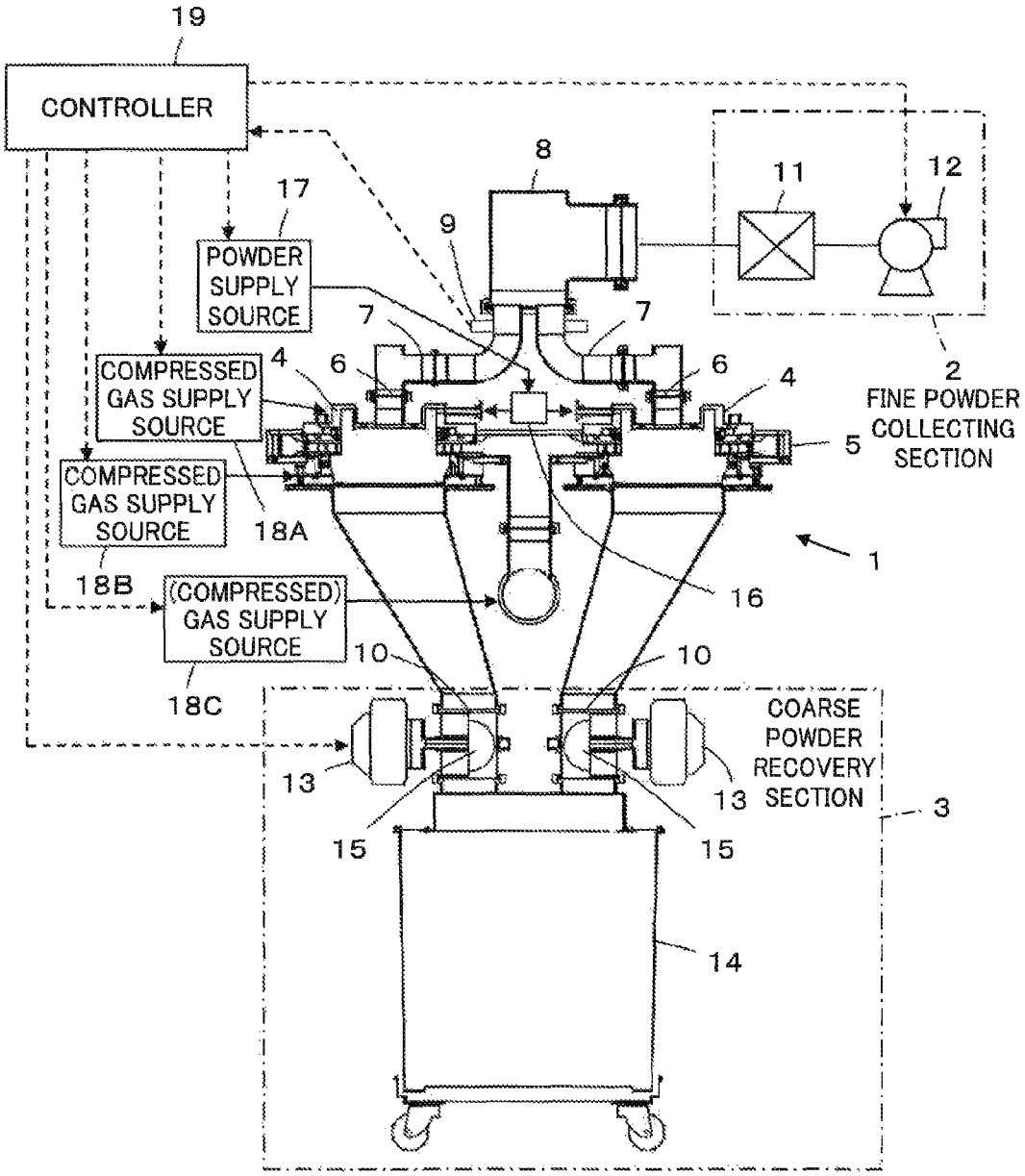
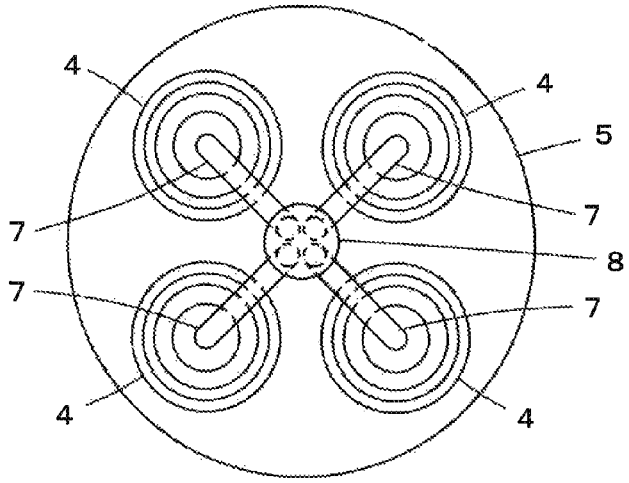

19
CONTROLLER
17
POWDER SUPPLY SOURCE
8
9
11
12
7
7
4
6
6
4
COMPRESSED GAS SUPPLY SOURCE
2
FINE POWDER COLLECTING SECTION
5
COMPRESSED GAS SUPPLY SOURCE
18A
1
18B
(COMPRESSED) GAS SUPPLY SOURCE
16
10
10
18C
COARSE POWDER RECOVERY SECTION
13
13
3
15
15
14

FIG.2


4
4
5
7
7
8
7
7
4
4

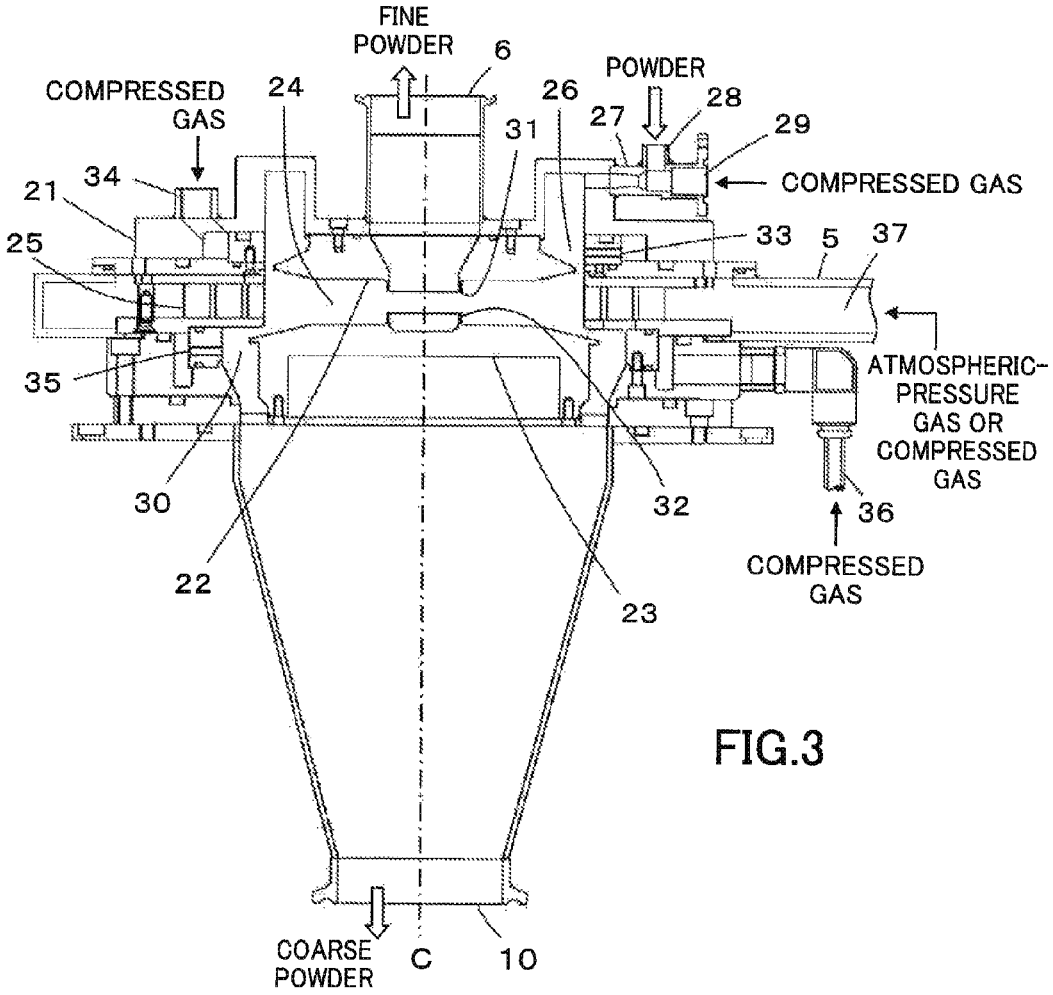

FINE POWDER
6
POWDER
COMPRESSED GAS
24
26
27
28
29
31
21
34
COMPRESSED GAS
25
33
5
37
35
ATMOSPHERIC-PRESSURE GAS OR COMPRESSED GAS
30
32
36
COMPRESSED GAS
22
23
COARSE POWDER
C
10

FIG.3

FIG.4

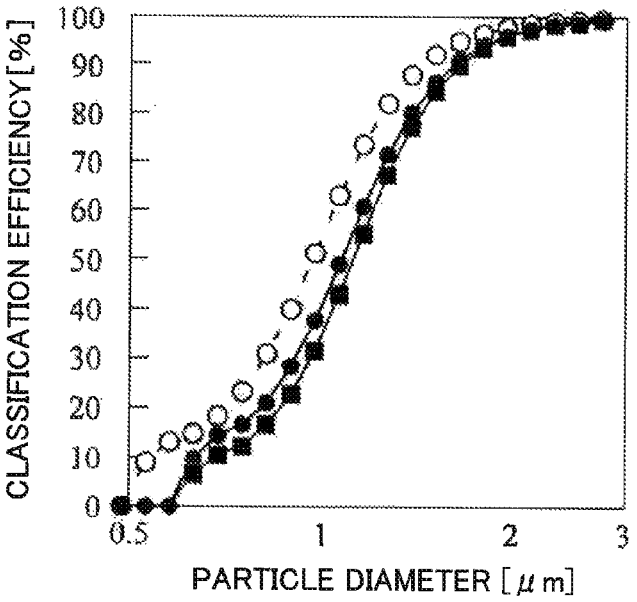

CLASSIFICATION EFFICIENCY [%]
100
90
80
70
60
50
40
30
20
10
0
0.5
1
2
3
PARTICLE DIAMETER [μm]

FIG.5

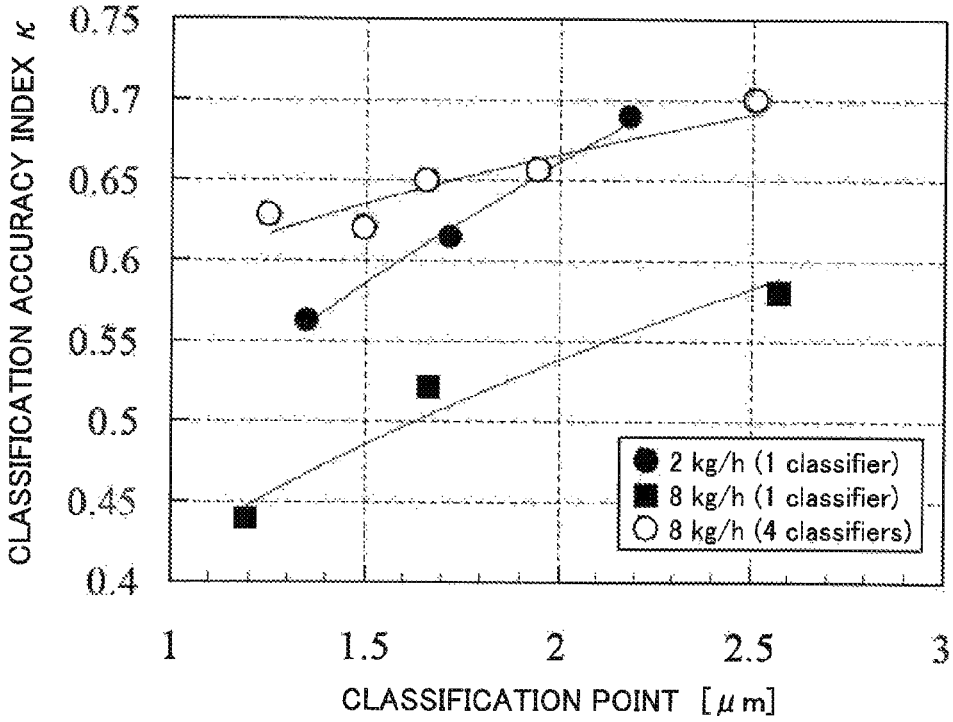
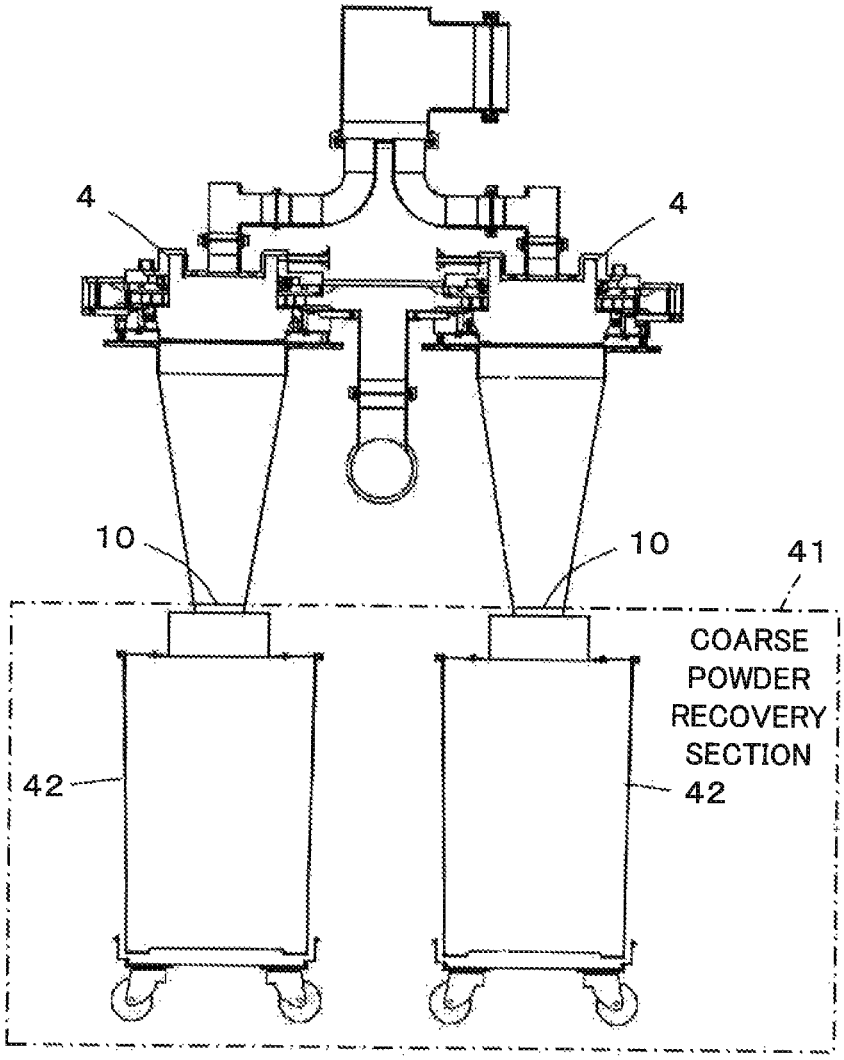

CLASSIFICATION ACCURACY INDEX κ
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
1
1.5
2
2.5
3
CLASSIFICATION POINT [μm]
2 kg/h (1 classifier)
8 kg/h (1 classifier)
8 kg/h (4 classifiers)

FIG.6



POWDER CLASSIFYING DEVICE

TECHNICAL FIELD

The present invention relates to a powder classifying device that classifies powder having a particle size distribution at a desired classification point and, in particular, to a powder classifying device that classifies a large amount of powder using a balance between a centrifugal force imparted to the powder by a whirling gas stream and a drag force generated by a gas stream.

BACKGROUND ART

There is known in the art a classifying device that uses guide vanes to generate a whirling gas stream, which imparts a whirling motion to powder, and centrifuges the powder into fine particles and coarse particles.

In a powder classifying device proposed in Patent Literature 1, for example, there are provided near the lower end of a cone-shaped powder passage a plurality of guide vanes disposed in upper and lower annular stages separated by a partition board. Exhaust air is discharged from an exhaust pipe, generating air circulation passing through the guide vanes. Powder that passes through the cone-shaped powder passage and falls into spaces between the upper guide vanes are caused to gyrate, so that the powder is classified according to the relationship between centrifugal force and drag.

Patent Literature 2 describes a material supply device in which guide vanes are disposed in an annular arrangement around a material supply cylinder and powder material supplied into the material supply cylinder is dispersed by introducing air from the outside through secondary air inlet passages between adjacent guide vanes. Air stream generated by suction and discharge through a discharge pipe causes the material to whirl at high speed in dispersion as it falls down the material supply cylinder, flows into a classifying chamber, and is therein centrifuged into coarse powder and fine powder.

Patent Literature 3 describes a stream-type classifying device comprising guide vanes disposed around a classifying chamber in an annular arrangement and air stream inlet passages provided between adjacent guide vanes, wherein powder supplied into the classifying chamber is caused to whirl at high speed by air suction and discharge through an exhaust pipe and centrifuged into fine powder and coarse powder.

CITATION LIST

Patent Literature

Patent Literature 1: JP 06-83818 B
Patent Literature 2: JP 08-57424 A
Patent Literature 3: JP 11-138103 A

SUMMARY OF INVENTION

Technical Problems

Such classifying devices using guide vanes generate a whirling air stream by causing air to pass through the guide vanes by suction and discharge through the discharge pipe using, for example, a blower to impart a whirling motion to the powder thereby to centrifuge the powder into coarse powder and fine powder.

However, in a powder classifying device that achieves classification of powder using the balance between centrifugal force imparted to the powder by a whirling air stream and drag force generated by gas flow, increasing the dimensions of the device and enlarging the volume of the classifying chamber in order to improve the processing capability increases the radial velocity of powder, which changes the classification point to a greater value, making classification into fine particles such as sub-micron powder difficult. This limited the processing capability for classification of fine particles.

It is an object of the present invention to solve the above conventional problems and provide a powder classifying device capable of classifying powder into fine particles with a high processing capability.

Solution to Problems

A powder classifying device of the invention comprises a plurality of powder classifiers that impart a whirling motion to powder with whirling gas streams to classify the powder into coarse powder and fine powder, a gas supply source that supplies the plurality of powder classifiers with gas for generating the whirling gas stream, a powder supplier that supplies the plurality of powder classifiers with powder having a particle size distribution, a fine powder collecting section that collects fine powder classified by each of the plurality of powder classifiers, a coarse powder collecting section that recovers coarse powder classified by each of the plurality of powder classifiers, and a controller that controls flow rates of gases supplied to the plurality of powder classifiers so that a classification point is substantially equal among the plurality of powder classifiers.

Preferably, each of the plurality of powder classifiers comprises: a casing including inside thereof a substantially disk-shaped centrifuge chamber; an annular powder dispersion chamber located on one side of the centrifuge chamber, disposed concentric with the centrifuge chamber, and communicating with the centrifuge chamber; and an annular powder re-classifying chamber located on another side of the centrifuge chamber, disposed concentric with the centrifuge chamber, and communicating with the centrifuge chamber; a plurality of guide vanes disposed so as to inwardly extend from an outer periphery of the centrifuge chamber at a given angle and adapted to cause gas to flow into the centrifuge chamber or a plurality of gas supply nozzles disposed at a given angle around the centrifuge chamber and adapted to supply gas into the centrifuge chamber; and a plurality of first nozzles that elect gas into the powder dispersion chamber to generate the whirling gas stream.

Each of the plurality of powder classifiers may comprise a plurality of second nozzles that eject gas into the powder re-classifying chamber to generate the whirling gas stream.

Preferably, the controller controls flow rates of gases admitted through the guide vanes of the plurality of powder classifiers or either of pressures and flow rates of gases supplied from the gas supply source to the plurality of powder classifiers so that pressure losses in the plurality of powder classifiers are substantially equal to each other.

The powder supplier may comprise a powder distributor that distributes powder to the plurality of powder classifiers. The powder supplier may comprise an ejector provided inside the casing so as to communicate with the powder dispersion chamber and adapted to supply powder into the powder dispersion chamber, and further the powder supplier may comprise both a powder distributor and an ejector.

Preferably, each of the plurality of powder classifiers comprises a fine powder outlet that discharges gas streams containing fine powder, and the fine powder collecting section comprises a common collector connected to the fine powder outlets of the plurality of powder classifiers.

Each of the plurality of powder classifiers may comprise a coarse powder outlet that discharges coarse powder; the coarse powder collecting section may comprise a plurality of dumpers connected to the coarse powder outlets of the plurality of powder classifiers, respectively, and a common collecting container connected to the plurality of dumpers. Alternatively, each of the plurality of powder classifiers may comprise a coarse powder outlet that discharges coarse powder, and the coarse powder collecting section may comprise a plurality of collecting containers connected to the coarse powder outlets of the plurality of powder classifiers.

Advantageous Effects of Invention

According to the present invention, the controller controls flow rates of gases admitted through the guide vanes of the plurality of powder classifiers or either of pressures and flow rates of gases supplied from the gas supply source to the plurality of powder classifiers so that classification points in the plurality of powder classifiers are substantially equal to each other, achieving classification of fine particles with a high processing capability using a plurality of powder classifiers.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** illustrates a configuration of a powder classifying device according to an embodiment of the invention.

FIG. **2** is a plan view of a powder classifying device body used in the embodiment.

FIG. **3** is a cross section illustrating an inner structure of a powder classifier used in the embodiment.

FIG. **4** is a graph showing a relationship between particle diameter and classification efficiency when the nozzle manufacturing dimensions vary.

FIG. **5** is a graph showing a relationship between classification point and classification accuracy index in the embodiment.

FIG. **6** is a front view of the powder classifying device and a coarse powder collecting section used in another embodiment.

DESCRIPTION OF EMBODIMENTS

The present invention is described in detail below based on the preferred embodiments illustrated in the accompanying drawings.

FIG. **1** illustrates a configuration of a powder classifying device according to an embodiment of the invention. The powder classifying device comprises a classifying device body s that classifies powder, a fine powder collecting section **2** and a coarse powder collecting section **3** connected to the classifying device body **1**.

The classifying device body **1** comprises powder classifiers **4** each of which imparts a whirling motion to powder by virtue of a whirling gas stream and thereby classifies the powder into coarse powder and fine powder. The powder classifiers **4** are connected to each other by a hollow, substantially disk-shaped connecting member **5**. The powder classifiers **4** each have a fine powder outlet **6**, which is connected to a junction pipe **8** through a fine powder discharge pipe **7**. The junction pipe **8** is connected to the fine powder collecting section **2**. Each fine powder discharge pipe **7** has a pressure sensor **9** that detects the outlet pressure of the corresponding powder classifier **4**. The powder classifiers **4** each have a coarse powder outlet **10**, which is connected to the coarse powder collecting section **3**.

The fine powder collecting section **2** comprises a collector **11**, such as a bag filter, which is connected to the junction pipe **8** of the classifying device body **1**, and a suction blower **12** connected to the collector **11**.

The coarse powder collecting section **3** comprises dumpers **13** connected to the respective coarse powder outlets **10** of the powder classifiers **4** and a common collecting container **14** connected to the dumpers **13**. The dumpers **13**, equipped with air-tight, rotatable valve plates **15**, intermittently discharge into the collecting container **14** the coarse powder remaining in the coarse powder outlets **10** of the respective powder classifiers **4**.

The powder classifiers **4** of the classifying device body **1** are connected to a powder supply source **17** through a powder distributor **16**. The powder supply source **17** supplies powder that is to be classified in the powder classifying device according to this embodiment and which has a particle size distribution. The powder distributor **16** distributes the powder introduced from the powder supply source **17** evenly among the powder classifiers **4**.

The powder classifiers **4** of the classifying device body **1** are connected to compressed gas supply sources **18**A and **186** that supply compressed gas and a (compressed) gas supply source **18**C that supplies gas or compressed gas.

The pressure sensors **9** of the classifying device body **1** are connected to a controller **19**, which is connected to the suction blower **12** of the fine powder collecting section **2**, the dumpers **13** of the coarse powder collecting section **3**, the powder supply source **17**, the compressed gas supply sources **18**A, **18**B, and the gas supply source **18**C.

As illustrated in FIG. **2**, the classifying device body **1** comprises four powder classifiers **4**. The powder classifiers **4** have the same inner structure.

As illustrated in FIG. **3**, there are provided in an upper position inside a casing **21** an upper disk-like member **22** and a lower disk-like member **23** positioned on a center axis C, one disposed opposite the other and separated by a given distance. Between the disk-like members **22** and **23** is defined a substantially disk-shaped centrifuge chamber **24**, around which are provided guide vanes **25** extending inwardly at a given angle. The guide vanes **25** are mounted on a rotary axis parallel to the central axis C so as to rotate between the upper disk-like member **22** and the lower disk-like member **23**. The vane opening angle of all the guide vanes **25** can be changed simultaneously by turning a rotary plate, not shown, to adjust the distance between adjacent guide vanes **25**.

In place of the guide vanes **25** disposed around the centrifuge chamber **24**, there may alternatively be provided around the centrifuge chamber **24** gas supply nozzles disposed at a given angle and connected to the gas supply source **18**C, so that the gas supply source **18**C supplies gas into the centrifuge chamber **24** through the gas supply nozzles.

The casing **21** includes therein an annular powder dispersion chamber **26** defined around the centrifuge chamber **24** and disposed concentric with the centrifuge chamber **24**. The powder dispersion chamber **26** communicates with the centrifuge chamber **24**. In FIG. **3**, there is provided an ejector **27** directed toward the powder dispersion chamber **26**. The ejector **27** has a powder inlet **28** and a compressed gas inlet **29**. The powder inlet **28** is connected to the powder distributor **16**; the compressed gas inlet **29** is connected to a compressed gas supply source, not shown, for the ejector.

Around the lower disk-like member **23**, there is defined an annular powder re-classifying chamber **30** along the outer periphery of the centrifuge chamber **24** and concentric with the centrifuge chamber **24**. The powder re-classifying chamber **30** communicates with the centrifuge chamber **24**.

The upper disk-like member **22** is connected to the fine powder outlet **6** opening toward the center of the centrifuge chamber **24**. The casing **21** has at its lower end the coarse powder outlet **10** communicating with the centrifuge chamber **24** through the powder re-classifying chamber **30**.

The upper disk-like member **22** has an annular edge portion **31** provided on the outer periphery of an opening, which communicates with the fine powder outlet **6**, and projecting toward the centrifuge chamber **24**; the lower disk-like member **23** has near its center and opposite the edge portion **31** an annular edge portion **32** projecting toward the centrifuge chamber **24**. Thus, the edge portions **31** and **32** are disposed on the opposite sides of the centrifuge chamber **24**.

In the peripheral wall defining the powder dispersion chamber **26**, first nozzles **33** are arranged so as to oppose the inside of the powder dispersion chamber **26** and connected to the compressed gas supply source **18**A through a compressed gas inlet **34**. In the peripheral wall defining the powder re-classifying chamber **30**, second nozzles **35** are disposed so as to oppose the inside of the re-classifying chamber **30** and connected to the compressed gas supply source **16**B through a compressed gas inlet **36**.

The first nozzles **33** are disposed at a given angle to a tangent to the annular powder dispersion chamber **26** and, likewise, the second nozzles **35** are disposed at a given angle to a tangent to the annular powder re-classifying chamber **30**. In such configuration, ejection of compressed gas from the first nozzles **33** or the first nozzles **33** and they second nozzles **35** causes whirling gas streams to be generated in the powder dispersion chamber **26** and the powder re-classifying chamber **30** that whirl in the same direction.

Around the outer periphery of the guide vanes **25**, which in turn are disposed around the centrifuge chamber **24**, there is located a compressed as forcing chamber **37** defined inside a hollow connecting member **5** and connected to the compressed gas supply source **18**C. In the above configuration, forcing compressed gas via the compressed gas forcing chamber **37** through the guide vanes **25** into the centrifuge chamber **24** causes a whirling gas stream to be generated in the centrifuge chamber **24** in the same direction as the whirling gas streams generated in the powder dispersion chamber **26** and the powder re-classifying chamber **30**.

Instead of forcibly introducing compressed gas, a gas at the atmospheric pressure may be allowed to flow through the guide vanes **25** into the centrifuge chamber **24**.

As described above, a whirling gas stream may be allowed to be generated in the centrifuge chamber **24** in the same direction as the whirling gas streams generated in the powder dispersion chamber **26** and the powder re-classifying chamber **30** by ejecting compressed gas from the gas supply nozzles disposed at a given angle around the centrifuge chamber **24**, instead of disposing the guide vanes **25**.

Next, the operation of the powder classifying device according to this embodiment is described below.

The valve plate **15** of each of the dumpers **13** of the coarse powder collecting section **3** needs to have been previously closed by the controller **19**.

First, the controller **19** operate the suction blower **12** of the fine powder collecting section **2**, whereupon a given amount of blown air is sucked into the centrifuge chamber **24** through the fine powder outlet **6** in each of the powder classifiers **4**, while the compressed gas supply sources **18**A and **18**B supply compressed gas to the compressed gas inlets **34** and **36** of each of the powder classifiers **4** for the first nozzles **33** and the second nozzles **35** to elect the compressed gas, and the compressed gas supply source **18**C supplies compressed gas to the compressed gas forcing chamber **37** of the connecting member **5**, so that the compressed gas is forcibly introduced through the guide vanes **25** of each of the powder classifiers **4**. Thus, whirling gas streams whirling in the same direction are generated in the powder dispersion chamber **26**, the centrifuge chamber **24**, and the powder re-classifying chamber **30** of each of the powder classifiers **4**.

In this state, the compressed gas is supplied from the compressed gas supply source (not shown) for the ejector to the compressed gas inlet **29** of the ejector **27** of each of the powder classifiers **4**, while powder is evenly distributed and supplied through the powder distributor **16** from the powder supply source **17** to the powder inlet **28** of the ejector **27** of each of the powder classifiers **4**, whereupon the powder is caused to enter the powder dispersion chamber **26** at a given flow rate by the compressed gas supplied through the compressed gas inlet **29**, where the powder, exposed to a whirling gas stream, is subjected to a whirling motion and is dispersed as it is allowed to fall through an annular gap formed around the upper disk-like member **22** into the centrifuge chamber **24**.

Because a whirling gas stream is also generated inside the centrifuge chamber **24**, the powder falling in from the powder dispersion chamber **26** is caused to whirl inside the centrifuge chamber **24** and thereby subjected to centrifugation. As a result, fine powder having a size not larger than a classification point (a particle cut size) is sucked and discharged together with the gas stream through the fine powder outlets **6**, while coarse powder having a large particle size is caused to remain by the annular edge portions **31** and **33** provided in the central portion of the centrifuge chamber **24**. Thus, fine powder can be sorted from powder having a particle size distribution and collected. The thus sorted fine powder scarcely contains coarse powder having a particle size larger than a classification point.

Thus, the fine powder discharged through the fine powder outlet **6** of each of the powder classifiers **4** passes through the fine powder discharge pipe **7** to reach the junction pipe **8**, where the fine powder discharged from the four powder classifiers **4** joins and is collected in the collector **11** of the fine powder collecting section **2**.

A detection signal sent from the pressure sensor **9** provided at the fine powder discharge pipe **7** of each of the powder classifiers **4** enters the controller **19**.

The remainder of the powder not discharged from the fine powder outlet **6** in each of the powder classifiers **4** is allowed to fall through an annular gap located around the lower disk-like member **23** from the centrifuge chamber **24** into the powder re-classifying chamber **30**. Accordingly, the powder allowed to fall into the powder re-classifying chamber **30** may often contain not only coarse powder larger than a classification point but fine powder not larger than a classification point. However, because the powder re-classifying chamber **30** contains a whirling gas stream generated by the compressed gas ejected from the second nozzles **35**, the fine powder is carried by the whirling gas stream back into the centrifuge chamber **24**. Thus, the fine powder is efficiently removed from the coarse powder and discharged from the fine powder outlet **6**.

After undergoing such re-classification in the powder re-classifying chamber **30**, coarse powder larger than a classification point is allowed to fall from the powder re-classifying chamber **30** down to the coarse powder outlet **10**.

As the coarse powder thus falls down to the coarse powder outlet **10** of each of the powder classifiers **4**, the valve plate **15** of the dumper **13** connected to the coarse powder outlet **10** of

each and every powder classifiers **4** is closed and thus prevents the coarse powder from being discharged into the collecting container **14**.

Should the valve plates **15** of all the dumpers **13** be opened simultaneously, gas might circulate between the powder classifiers **4** through the dumpers **13** and the collecting container **14**, possibly disturbing the whirling gas streams generated inside the powder classifiers **4**. This might reduce classification accuracy.

Therefore, the controller **19** operates only one of the dumpers **13** and keeps the valve plate **15** thereof open for a given period of time to allow the coarse powder classified by the powder classifier **4** connected to said dumper **13** to be discharged into the collecting container **14**. Upon elapse of the given period of time, the valve plate **15** of the dumper **13** is closed again, whereupon the valve plate **15** of the next dumper **13** is opened for the given period of time. Thus, the coarse powder classified by the powder classifier **4** connected to the next dumper **13** is discharged into the collecting container **14**. The valve plates **15** of the dumpers **13** are likewise sequentially opened one at a time to discharge coarse powder into the collecting container **14**.

Thus opening the valve plates **15** of the dumpers **13** sequentially one at a time instead of opening the valve plates **15** of the dumpers **13** all simultaneously enables collecting of coarse powder in the collecting container **14** without reducing the classification accuracy. Each of the dumpers **13** may be, for example, a device such as a shutter having an opening and closing structure, provided that the device can be so controlled as described above.

While the four powder classifiers **4** implement powder classification as described above, the controller **19** calculates pressure losses in the powder classifiers **4** based on detection signals sent from the pressure sensors **9** provided at the respective fine powder discharge pipes **7** of the powder classifiers **4**. The pressures and/or the flow rates of the gases supplied from the compressed gas supply sources **18**A, **18**B and the gas supply source **180** to the powder classifiers **4** are controlled so that the calculated pressure losses in the four powder classifiers **4** are equal. The supply of gases from the compressed gas supply sources **18**A, **18**B and the gas supply source **18**C to the ejector **27**, the compressed gas forcing chamber **37**, the gas supply nozzles provided around the centrifuge chamber **24**, the first nozzles **33**, and the second nozzles **35** can be adjusted individually as can the pressures and the flow rates of the ejected gases. Some of these may be controlled and the others may be kept constant. Control of the pressure and/or flow rate at the first nozzles **33** is particularly important in the adjustment of the classification point.

In a classifying device that classifies powder into coarse powder and fine powder by generating a whirling gas stream and imparting a whirling motion to the powder by virtue of the whirling gas stream, typically, the classification point depends on the intensity of the whirling gas stream, and the intensity of the whirling gas stream is correlated with the pressure loss in the classifier, when the dimensions of the classifier are identical. Therefore, when the pressure losses in the four powder classifiers **4** are adjusted to be equal, the intensities of the whirling gas streams generated inside the respective powder classifiers **4** are equal, and the classification points in the powder classifiers **4** can be equalized. As a result, a high-accuracy classification is achieved even when the four powder classifiers **4** are operated in parallel to increase the processing capability.

More specifically, the pressure losses in the four powder classifiers **4** can be equalized by adjusting the pressures at the first nozzles **33** or the first nozzles and the second nozzles **35** of the powder classifiers **4** or by adjusting the flow rates of the compressed gases ejected from the first nozzles **33** or the first nozzles **33** and the second nozzles **35** of the powder classifiers **4** with flow rate adjusters, such as flow rate adjusting valves, to be provided between the compressed gas supply sources **18**A, **18**E and the compressed gas inlets **34**, **36** of the respective powder classifiers **4**.

Alternatively, the pressure losses in the four powder classifiers **4** can be equalized by adapting the controller **19** to change the vane opening angle of the guide vanes **25** in the powder classifiers **4** so as to adjust the flow rates of the gases forced into the centrifuge chambers **24** of the powder classifiers **4**.

Alternatively, the pressure losses in the four powder classifiers **4** can be equalized by adjusting the flow rates of the compressed gases flowing into the powder classifiers **4** using flow rate adjusters provided between the compressed gas supply source, not shown, and the compressed gas inlets **29** of the ejectors **27** of the powder classifiers **4**. In this case, however, changing the flow rates of the compressed gases admitted through the compressed gas inlets **29** of the ejectors **27** may change the amounts of supplied powder from the powder supply source **17** to the powder classifiers **4**.

Further, even where the four powder classifiers **4** used have the same structure, there may arise a variation in the classification point among the powder classifiers due to, for example, variations in dimensions among component parts caused by manufacturing tolerances. For example, FIG. **4** illustrates classification efficiency in relation to particle diameter as the diameter of the first nozzles **33** change. In the graph, black squares indicate the classification efficiency obtained with a nozzle diameter of 1.3 mm, a gas pressure of 0.6 MPa, and a gas flow rate of 626 liters/min; and white circles indicate the classification efficiency obtained a nozzle diameter of 1.4 mm, a gas pressure of 0.6 MPa, and a gas flow rate of 739 liters/min. The graph shows that with the same gas pressure, the classification point varies greatly as the nozzle diameter and the gas flow rate change.

The classification efficiency indicated by black circles in the graph was obtained with a nozzle diameter of 1.4 mm, a gas pressure of 0.48 MPa, and a gas flow rate of 619 liters min. Even when the nozzle diameter changes from 1.3 mm to 1.4 mm, the classification point can be brought close to that resulting from the use of nozzles having a diameter of 1.3 mm indicated by the black squares through adjustment of the gas pressure and the gas flow rate.

Thus, even where the manufacturing dimensions vary, the classification accuracy can be enhanced by adjusting the flow rates of the gases supplied from the compressed gas supply sources **18**A, **18**B and the gas supply source **18**C to the powder classifiers **4**.

Now, in the embodiment of the powder classifying device, powder in a total amount of 8 kg/h was classified by supplying powder at a flow rate of 2 kg/h to each of the four powder classifiers **4** connected to each other, and a classification accuracy index κ was measured for various classification points. The result is indicated by white circles in FIG. **5**. For comparison, black circles indicate measurements obtained when only one powder classifier **4** was used to classify powder supplied at a flow rate of 2 kg/h, and black squares indicate measurements obtained when only one powder classifier **4** was used to classify powder supplied at a flow rate of 8 kg/h.

The classification accuracy index κ is expressed as a ratio of 25% cut size D25 to 75% cut size D75. That is, κ=D25/D75

As shown by FIG. **5**, a higher classification accuracy is achieved using the powder classifying device according to the embodiment wherein the four powder classifiers **4** are con-

nected to classify powder at a flow rate of 8 kg/h than when only one powder classifier **4** is used to classify powder supplied at a flow rate of 8 kg/h.

In the powder classifying device according to the embodiment, the controller **19** controls the flow rates of the gases supplied from the compressed gas supply sources **181**, **18**E and the gas supply source **18**C to each of the powder classifiers **4** so as to generate stable whirling gas streams in the powder classifiers **4**, enabling a high-accuracy classification of sub-micron particles having a diameter smaller than, for example, 1 μm.

Powders that can be classified by the present invention range from low specific-gravity powders such as powders of silica and toners to high specific-gravity powders such as powders of metals and alumina.

Gases supplied from the compressed gas supply sources **18**A, **18**B and the gas supply source **180** may be compressed air or, depending on the powder to be classified, inactive gas, for example.

The powder distributor **16** that distributes powder from the powder supply source **17** to the powder classifiers **4** may be any distributor known in the art such as, for example, a distributor of a type that distributes powder using whirling gas streams. Use of the powder distributor **16** is not essential. For example, a hopper may be connected to the powder inlet **28** of the ejector **27** of each of the powder classifiers **4** to store powder in the hopper, and powder therein may be supplied by means of the ejector **27**.

In the above embodiment, circulation of gases between the powder classifiers **4** is prevented by opening the valve plates **15** of the dumpers **13** sequentially one at a time. Connection of a so-called double-dumper, which, equipped with a pair of serially disposed valve plates, can discharge powder while maintaining airtightness, to the coarse powder outlet **10** of each of the powder classifiers **4** enables simultaneous discharge of coarse powder from a plurality of powder classifiers **4** while preventing gas circulation between the powder classifiers **4**.

A coarse powder collecting section **41** as illustrated in FIG. **6** may also be used. Using the coarse powder collecting section **41**, dedicated collecting containers **42** are connected to the respective coarse powder outlets **10** of the powder classifiers **4** without the intermediary of dumpers.

In such a configuration, where four separate collecting containers **42** are provided individually for the respective four powder classifiers **4**, as circulation between the powder classifiers **4** through a common collecting container never occurs. Therefore, simultaneous discharge of coarse powder from a plurality of powder classifiers **4** is made possible without reducing the classification accuracy.

While four powder classifiers **4** are connected to each other in the above embodiment, the number of powder classifiers is not limited to four and may be 2, 3, 5 or more units thereof may be connected.

While the annular edge portions **31** and **32** are disposed on the opposite sides of the centrifuge chamber **24** in each of the powder classifiers **4** in the above embodiment, only one of the edge portions **31** and **32** may be provided.

While the powder classifiers **4** in the above embodiment use both the first nozzles **33** provided so as to oppose the inside of the powder dispersion chamber **26** and the second nozzles **35** provided so as to oppose the inside of the powder re-classifying chamber **30**, the second nozzles **35**, for example, may be omitted.

Instead of using the guide vanes **25**, use may be made of a powder classifier in which the centrifuge chamber **24** is closed on the outer peripheral side thereof by a peripheral wall member.

REFERENCE SIGNS LIST

1 classifying device body; **2** fine powder collecting section; **3**, **41** coarse powder collecting section; **4** powder classifier; **5** connecting member; **6** fine powder outlet; **7** fine powder discharge pipe; **8** junction pipe; **9** pressure sensor; **10** coarse powder outlet; **11** collector; **12** suction blower; **13** dumper; **14**, **42** collecting container; **15** valve plate; **16** powder distributor; **17** powder supply source; **18**A, **18**B compressed gas supply source; **18**C gas supply source; **19** controller; **21** casing; **22** upper disk-like member; **23** lower disk-like member; **24** centrifuge chamber; **25** guide vanes; **26** powder dispersion chamber; **27** ejector; **28** powder inlet; **29**, **34**, **36** compressed gas inlet; **30** powder re-classifying chamber; **31**, **32** edge portion; **33** first nozzle; **35** second nozzle; **37** compressed gas forcing chamber.

The invention claimed is:

1. A powder classifying device comprising:

a plurality of powder classifiers that impart a whirling motion to powder with whirling gas streams to classify the powder into coarse powder and fine powder, each of the plurality of powder classifiers including a coarse powder outlet that discharges coarse powder,

a gas supply source that supplies the plurality of powder classifiers with gas for generating the whirling gas stream,

a powder supplier that supplies the plurality of powder classifiers with powder having a particle size distribution,

a fine powder collecting section that collects fine powder classified by each of the plurality of powder classifiers,

a plurality of dumpers corresponding to the plurality of powder classifiers, each dumper being connected to the coarse powder outlet of the corresponding powder classifier to open and close the coarse powder outlet of a corresponding powder classifier,

a coarse powder collecting container common to the plurality of power classifiers, the coarse powder collecting container being connected to the plurality of dumpers to recover coarse powder classified by each of the plurality of powder classifiers, and

a controller that controls flow rates of gases supplied to the plurality of powder classifiers so that a classification point is substantially equal among the plurality of powder classifiers,

wherein the plurality of dumpers open the coarse powder outlets of the plurality of powder classifiers sequentially one at a time to discharge coarse powder into the coarse powder collecting container to prohibit circulation of gases between the plurality of powder classifiers through the plurality of dumpers and the common coarse powder collecting container.

2. The powder classifying device according to claim **1**, wherein each of the plurality of powder classifiers comprises:

a casing including inside thereof a substantially disk-shaped centrifuge chamber, an annular powder dispersion chamber located on one side of the centrifuge chamber, disposed concentric with the centrifuge chamber, and communicating with the centrifuge chamber, and an annular powder re-classifying chamber located on another side of the centrifuge chamber, disposed

concentric with the centrifuge chamber, and communicating with the centrifuge chamber;

a plurality of guide vanes disposed so as to inwardly extend from an outer periphery of the centrifuge chamber at a given angle and adapted to cause gas to flow into the centrifuge chamber or a plurality of gas supply nozzles disposed at a given angle around the centrifuge chamber and adapted to supply gas into the centrifuge chamber; and

a plurality of first nozzles that eject gas into the powder dispersion chamber to generate the whirling gas stream.

3. The powder classifying device according to claim **2**, wherein each of the plurality of powder classifiers comprises a plurality of second nozzles that eject gas into the powder re-classifying chamber to generate the whirling gas stream.

4. The powder classifying device according to claim **2**, wherein the controller controls flow rates of gases admitted through the guide vanes of the plurality of powder classifiers so that pressure losses in the plurality of powder classifiers are substantially equal to each other.

5. The powder classifying device according to claim **1**, wherein the controller controls either of pressures and flow rates of gases supplied from the gas supply source to the plurality of powder classifiers so that pressure losses in the plurality of powder classifiers are substantially equal to each other.

6. The powder classifying device according to claim **1**, wherein the powder supplier comprises a powder distributor that distributes powder to the plurality of powder classifiers.

7. The powder classifying device according to claim **1**,

wherein each of the plurality of powder classifiers comprises a fine powder outlet that discharges gas streams containing fine powder, and

wherein the fine powder collecting section comprises a common collector connected to the fine powder outlets of the plurality of powder classifiers.

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